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Winter Heating or Clean Air? Unintended Impacts of China's Huai River Policy

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III. ASSA Program Information

Session Title: Air Pollution and Health Around the World
Session Chair: Janet Currie
Discussants: Heather Royer, Matthew Neidell, and Lucas Davis

PRELIMINARY AND INCOMPLETE
NOT FOR ATTRIBUTION

Winter Heating or Clean Air? Unintended Impacts of China's Huai River Policy

By DOUGLAS ALMOND, YUYU CHEN, MICHAEL GREENSTONE, and HONGBIN LI*

Air quality in China is notoriously poor. Ambient concentrations of Total Suspended Particulates (TSP) 1981-1993 were more than double China's National Annual Mean Ambient Air Quality Standard of 200 mg/m^{-3} (Bi et al., 2007) and five times the level that prevailed in the US level before the passage of the Clean Air Act in 1970. Further, it is frequently claimed that air quality is especially poor in Northern Chinese cites. For example, following a career in the Southern China city of Shanghai, Prime Minister Zhu Rongi reportedly quipped in 1999: "If I work in your Beijing [a North China city], I would shorten my life at least five years" (*The Economist,* 2004).

This paper assesses the role of a seemingly arbitrary Chinese policy in producing dramatic differences in air quality within China. During the 1950-1980 period of central planning, the Chinese government established free winter heating of homes and offices via the provision of free coal for fuel boilers as a basic right. The combustion of coal in boilers is associated with the release of air pollutants, especially TSP. Due to budgetary limitations, however, this right was only extended to areas located in North China. The line formed by the Huai River and Qinling Mountains denotes the border between North and South China.

Using a unique data file on air pollution concentration in 76 Chinese cities, we find that the heating policy led to dramatically higher TSP levels in North China. This result holds in a

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cross-sectional regression discontinuity-style estimation approach and in a panel data setting that compares the marginal effect of winter temperature on TSP in North and South China, after controlling for all permanent city-level determinants of TSP concentrations and transitory ones common to all Chinese cities. In contrast, we fail to find evidence that the heating policy leads to increases in sulfur dioxide (SO_2) and nitrogen oxide (NO_x) concentrations.

I. Brief Background on China's Heating System and Huai River Policy

China's heating system was established during the three decades of the planned regime, 1950-1980. In this period, heating was considered a basic right and the government provided free heating to homes and offices, either directly or through state-owned enterprises. Commercial heating did not arrive in China until the mid-1990s after our analysis ends. The legacy of this system remains today as many homes and offices continue to receive free heat.

Due to budgetary limitations, the Chinese government limited the free heating policy to areas located in North China. The border between North China and South China are determined by the line formed by the Huai River and Qinling Mountains. The average January temperature is roughly 0° Celsius along this line.

Northern Chinese cities received free unlimited heating between November 15 and March 15. In contrast, heating was (and largely remains) non-existent to the South because the government did not supply heating facilities and there wasn't a private sector to supply it until recently. Indeed, it is widely recognized that winters are cold and uncomfortable in cities that are just south of the Huai River, like Nanjing, Shanghai, and Chengdu.

The Chinese heating system is coal-based and technically inefficient. Most heat was and is provided by coal-fired heat-only boilers or combined heat and power generators, which are inefficient in energy usage compared to electric, gas and oil heating systems in industrial countries (Wang et al., 2000; Jiang, 2007). For a residential building, heat typically comes from a boiler in the building or one in a heating factory, both of which burn coals to heat water and then sends the heated water to each household through iron pipes. In the latter case, the heated water frequently travels long distances before reaching a household, during which there is substantial energy loss.

The incomplete combustion of coal in these boilers leads to the release of air pollutants. There is little doubt that this causes substantial TSP emissions. We are currently investigating what other pollutants are likely to be released. Since data on ambient concentrations of SO_2 and NO_x are available, we are especially interested in whether the combustion of coal in these boilers is likely to lead to substantial emissions of these pollutants. Vehicles are a primary source of NO_x, so it may be reasonable to assume that the heating policy should have little impact on ambient NO_x concentrations.

There is some evidence that this heating policy leads to substantial increases in pollution concentrations during the winter months. Fan et al. (2004) show that in Yinchuan, total suspended particulates (TSP) concentrations are significantly higher in the winter than the rest of the year. In the capital city of Xinjiang, Wulumuqi, 90% of the pollutants in the winter are emitted from the heating system (Tianshan 2006). Qiu and Yang (2000) find that visibility in five northern cities in winter was much lower than the rest of the year between 1980 and 1994.

This paper's central task is to provide the first systematic documentation of the impacts of China's Huai River Policy on air pollution concentrations. This is done in two ways. First, we test whether concentrations are higher in Northern cities, relative to Southern ones, after adjustment for a polynomial in latitude. This test has some similarities with a regression discontinuity-style approach that has become increasingly popular in recent years (Cook and Campbell 1979; Greenstone and Gallagher 2008; Almond et. al. 2008). Second, we test whether concentrations are higher in Northern cities, relative to their long run average, after adjustment for the realized temperature in year. This approach takes advantage of the substantial inter-annual variation in temperature to compare ambient concentrations in Northern and Southern cities in years where the ambient temperatures are similar.

II. Data Sources and Descriptive Statistics

This paper utilizes two primary data sets. The first is a city by year data file that reports annual daily average concentrations of TSP, SO_2, and nitrogen oxides NO_x during the period 1980-1995. The data file is unbalanced and a total of 76 cities have a recorded concentration for at least one pollutant in one year. These pollution data were downloaded from a World Bank web site and are part of its "Economics of Pollution Control Research" project. The World Bank compiled the 1981-1990 data from the China Environmental Quality Report, produced by the China National Environmental Monitoring Station, dated July, 1991 and the 1991-1995 data from the China Environment Yearbooks from China's State Environmental Protection Administration.

The second data file is monthly average temperature data that is reported at the city-level. It was collected from the China Meteorological Administration and covers the years 1980-1993 so our analysis will be limited to these years. Furthermore, city temperatures are reported by month. We calculate winter temperature as the average temperature for November-February.

Figure 1 shows the location of each city in our analysis. The Huai River/Qinling Mountains line is the dark line in the figure that divides China into its North and South.

Although the line ranges between 33.03° and 34.25° latitude, there are not any cities at the same latitude that are on different sides of the line.

Table 1 reports summary statistics for some key variables. Most striking is the levels of air pollution concentrations. For comparison, the average US TSP concentration among monitored cities ranged between 100 mg/m^3 (1964) and 42 mg/m^3 (1993) during the years 1964-1998. Further, the standard deviation of the annual city-specific means ranged between 13 (1992 and 1993) and 61 mg/m^3 (1970).[1]

The table documents that mean TSP concentrations over the 1980-1995 period were 538 mg/m^3 in China. Further, the standard deviation of the annual city-level means was 330 mg/m^3! The mean SO_2 concentration in the China data is 109 mg/m^3, which is substantially greater than the 1990 US average of 23 mg/m^3. Notably, the NOx concentrations are closer in the US (40.5 mg/m^3) and China (56.5 mg/m^3). This may reflect the relatively low levels of motor vehicle usage in China during this period.

It is evident that China provides an unique opportunity to study the impacts of air pollution concentrations on willingness to pay for clean air and human health at levels that far exceed those ever recorded in the US or other any other country. The availability of this data is a key ingredient in any such study, but an equally important one is the identification of plausibly exogenous variation in air pollution. The remainder of the paper explores whether China's Huai River policy provides variation in air pollution at these extraordinary concentrations.

III. Econometric Strategy

This section describes the two econometric models used to the impact of the Huai River

[1] The US TSP calculations are derived from monitor-level TSP data that the authors obtained by filing a freedom of information act request with the EPA. See Chay and Greenstone (2003 and 2005) for further details on these data.

Policy on air pollution concentrations. The Model 1 equation is:

(1) $TSP_{ct} = \alpha + \beta\, 1(North)_c + \boldsymbol{\pi}\, f(Latitude)_c + \boldsymbol{\mu}_t + \varepsilon_{ct},$

where c references a city and t indexes a year. The dependent variable is the average daily TSP concentration in a city by year. (We also estimate models for SO_2 and NO_x concentrations.) The outcome is adjusted for a polynomial of degrees latitude, which adjusts for any association between this variable and air pollution concentrations (e.g., due to temperature, topography, hours of daylight, etc.). Additionally, the model includes year fixed effects, $\boldsymbol{\mu}_t$, to capture the influence of the business cycle in the unbalanced panel.

The parameter of interest is β, the coefficient on the indicator variable $1(North)_c$: whether the city lies above or below the Huai River line. It assesses whether pollution concentrations are higher in Northern cities, after flexibly adjusting for their latitude and the year fixed effects. The threat to obtaining unbiased estimates of the policy from Model 1 is the possibility that there may be important unobserved permanent or transitory determinants of air pollution concentrations in Northern cities that changes discretely at the Huai River line.

Therefore, we also estimate the following equation, which we refer to as Model 2:

(2) $TSP_{ct} = \alpha + \rho\, Winter\ Temperature_{ct} + \lambda\, \{Winter\ Temperature_{ct} \times 1(North)_c\}$

$+ \boldsymbol{\delta}_c + \boldsymbol{\mu}_t + \varepsilon_{ct}.$

This equation adjusts for the realized winter temperature and city fixed effects, $\boldsymbol{\delta}_c$, as well as the year fixed effects. Importantly, the city fixed effects removes permanent differences in air pollution concentrations across cities, and thereby addresses a limitation of Model 1.

The parameter of interest is λ. It tests whether the marginal effect of winter temperature on TSP in North and South China differs after adjustment for the city and year fixed effects. Due to the Huai River/Qinling Mountains based heating policy, Northern households can respond to cold temperatures by altering their consumption of heat derived from coal-based sources. South China households do not have this opportunity. Consequently, λ provides a second test for this policy's negative externalities, measured by air quality.

III. Results

Figure 2 previews the Model 1 TSP results visually. It plots the bivariate relation between a city's average TSP concentration calculated for all available years from 1980-1995 and its latitude. The plots are done separately for cities to the North and South of the Huai River/ Qinling Mountains line and come from the estimation of nonparametric regressions that use Cleveland's (1979) tricube weighting function and a bandwidth of 0.5. Thus, they represent a moving average of the TSP concentration across 1982 HRS scores. The data points represent each city's mean TSP concentration.

The figure presents dramatic evidence that Northern cities have higher TSP concentrations. An especially convincing feature of the graph is the evidence of a discontinuous increase in TSP concentrations at latitudes just above the Huai River line. This jump is meaningful, because it seems improbable that other determinant of air pollution change as discretely to the North of the line as the heating policy.

We begin by focusing on the Model 1 TSP results, which are in the first three columns of the top panel. The column (1) specification controls for latitude. Column (2) adds the square of latitude as a covariate and then column (3) adds a cubic to the column (2) specification. The striking finding from columns (1) and (2) is that TSP concentrations are roughly 300 mg/m^3 higher in Northern cities. To put this in perspective, this statistically significant difference is more than three times the concentration of TSP that prevailed in the United States before the passage of the Clean Air Act in 1970. In the richer, but possibly over-parameterized column (3) specification, the difference declines to 200 but would still be judged to be statistically different from zero at conventional levels.[2]

The Model 1 SO_2 and NO_x results generally indicate higher concentrations in Northern cities. However, the standard errors are larger relative to the mean levels of these variables. Further, they are poorly determined and none of them would be judged to be statistically significant at conventional levels.

We also conducted a falsification exercise based on the location of the Yangtze River. In particular, we denoted all cities to the North of this River as Northern cities and labeled the others as Southern cities. Since there is not a heating policy based on the Yangtze River, the null hypothesis is that pollution concentrations are equal to the North and South of the river. Indeed, the fitting of a version of Model 1 that utilizes theses Yangtze based designations fails to find evidence of higher TSP concentrations to the North of the Yangtze River. Similarly, we cannot reject the null that SO_2 and NO_x concentrations are equal in the North and South of the Yangtze.[3]

The lower panel presents the results from two versions of Model 2; we first focus on the TSP results. The column (1) specification simply includes the main effect for the winter temperature variable. The entry indicates that across the entire sample there is little evidence of a relationship between winter temperatures deviations and TSP concentrations. The column (2) specification adds the interaction between winter temperature and an indicator for the city being North of the heating line. It is evident that an abnormally cold winter increases TSP concentrations, relative to the impact of an equally cold winter in a Southern city. Specifically, a 1° F decrease in the winter temperature is associated with an increase in the TSP concentration of

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[2] In results available upon request, adjustment for longitude does not substantially affect the estimates of β.
[3] Space constraints prevent the reporting of these results here, but they are available upon request.

52 mg/m^3. Again, the size of this impact is enormous relative to current US TSP levels.

Model 2 also fails to find evidence that the heating policy affects SO_2 and NO_x concentrations. These estimates are also poorly determined. As we described above, we cannot yet assess whether it is reasonable to expect the heating policy to lead to increases in the concentrations of these pollutants in North China. Thus, at this point, we simply note the absence of an association between the policy and concentrations of these pollutants.

IV. Discussion and Future Directions

Using a unique data file on air pollution concentration in 76 Chinese cities, this paper has demonstrated that the Huai River/Qinling Mountains heating policy leads to dramatically higher TSP levels in Northern China. This result holds in a cross-sectional regression discontinuity-style estimation approach and in a panel data setting that compares pollution concentrations in Northern and Southern cities in years when they have similar winter temperatures. In contrast, we fail to find evidence that the heating policy leads to increases in SO_2 and NO_x concentrations.

More broadly, this paper has uncovered a source of variation in air pollution that can be used to study the impacts of air quality on human health and individuals' valuations of clean air at pollution concentrations that far exceed those ever recorded in the US or any other country. An important direction for future research is to find the data sets that will allow for such studies.

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Table 1: Summary Statistics for Key Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
Total Suspended Particulates (mg/m^3)	399	538	330	80	2770
Sulfur Dioxide (mg/m^3)	449	109	82.2	2	520
Nitrogen Oxides (mg/m^3)	401	56.5	24.6	7	164
Winter Temperature (°F)	455	35.7	13.6	3.74	68.4
Year	455	1987	3.90	1981	1993
Latitude (° North)	455	35.0	6.35	20.1	47.3
1(North of Huai River)	455	.613	.488	0	1

Notes: The entries are calculated across all non-missing city observations during the 1980-1993 period. The data file is unbalanced and a total of 76 cities have a recorded concentration for at least one pollutant in one year. 58 cities have at least one year of non-missing total suspended particulates data. The same 58 cities have at least one year of non-missing sulfur dioxide data. A total of 41 cities have non-missing nitrogen oxides data.

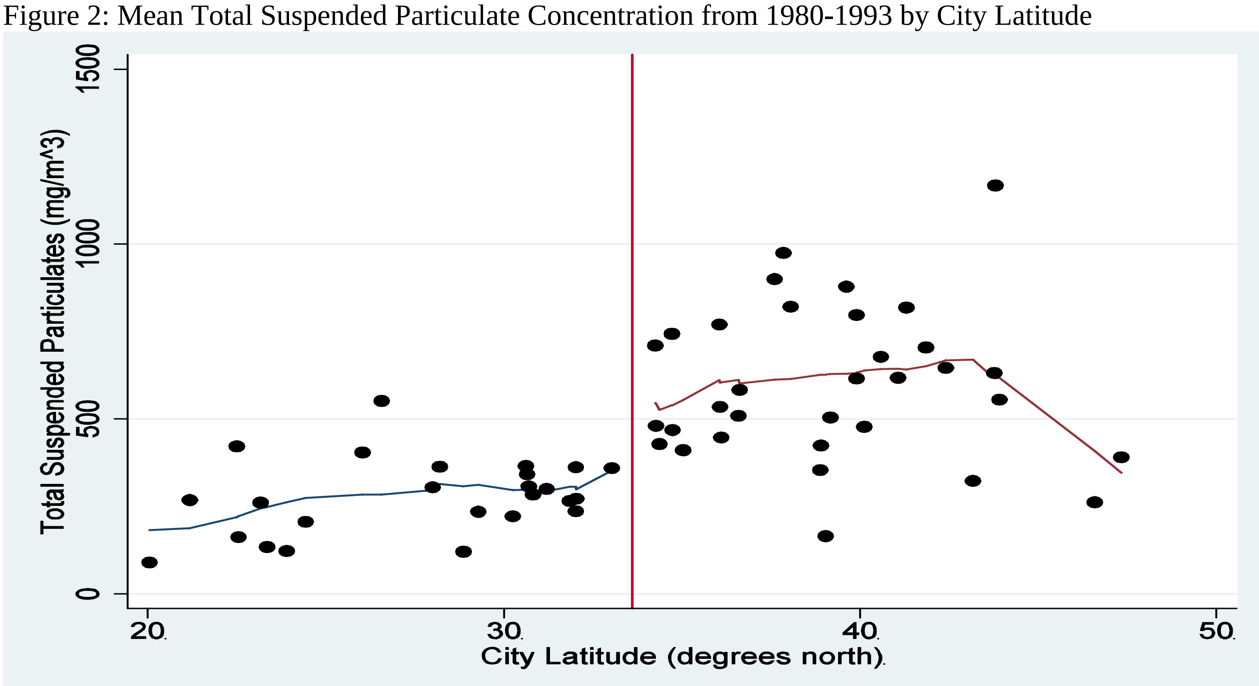
Table 2: Estimated Impacts of Huai River/Qinling Mountains Policy on Air Pollution Concentrations

	Total Suspended Particulates			**Sulfur Dioxide**			**Nitrogen Oxides**		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Model 1									
1(North)	318***	312***	204***	37.1	33.3	29.4	10.1	8.55	-4.40
	[96.2]	[80.4]	[96.5]	[33.0]	[32.3]	[48.3]	[10.4]	[10.1]	[12.0]
Observations	399	399	399	449	449	449	401	401	401
R-Squared	.44	.44	.47	.00	.01	.01	.08	.08	.08
Latitude	Y	Y	Y	Y	Y	Y	Y	Y	Y
Latitude Squared	N	Y	Y	N	Y	Y	N	Y	Y
Latitude Cubic	N	N	Y	N	N	Y	N	N	Y
Year Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y
Model 2									
Winter Temperature	-5.47	37.8**		-.534	-.653		-1.28	-1.48	
	[13.8]	[18.7]		[2.42]	[2.59]		[.876]	[1.40]	
1(North) * Winter Temperature		-51.8**			0.145			0.250	
		[22.2]			[2.187]			[1.42]	
Observations	399	399	399	449	449	449	401	401	401
R-Squared	.63	.64	.65	.86	.86	.86	.57	.57	.57
City Fixed Effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Year Fixed effect	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes: The table reports estimation results from fitting versions of equations (1) and (2). In addition to some regression statistics, the table reports key parameter estimates and estimated standard errors below (in brackets). The standard errors are clustered at the city level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. See the text for further details.

Figure 1: North and South China Denoted by Huai River/Qinling Mountains 0° Celsius Line

Figure 2: Mean Total Suspended Particulate Concentration from 1980-1993 by City Latitude



Notes: The vertical line is drawn at 33.6°, which is in the middle of the latitude range covered by the Huai River/ Qinling Mountains line.